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THE BY-PASS OPERATION IN THE TREATMENT OF ARTERIOSCLEROTIC OCCLUSIVE DISEASE OF THE LOWER EXTREMITIES

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DURING THE PAST FEW YEARS the surgical approach to arteriosclerotic segmental occlusive disease of the peripheral arteries has been directed toward re-establishment of blood flow through the main arterial channels. Although numerous technical variations are possible, in general three types of procedures have been employed for this purpose. These are endarterectomy, excision and graft replacement of the occluded segment, and by-pass of the diseased area with a graft.

Our experience with these methods of treatment, like that of others, has disclosed a number of factors, both technical and physiologic, that are essential to the success or failure of the operation. Most important among these are: first, the presence of an adequate patent peripheral arterial bed for the ready and unimpeded outflow of blood and, second, the performance of the procedure in a manner that will minimize tissue damage as well as interference with collateral circulation. The former can be established by proper arteriographic studies which should demonstrate not only the limits of the occlusive process but also the character of the peripheral arterial bed well beyond the distal point of the occlusion, as Lindbom has pointed out. The latter is concerned primarily with certain technical considerations that have an important bearing upon the outcome of the procedure. Operative trauma to adjacent structures, such as veins, lymphatics, and nerves, must be minimized to prevent troublesome and even incapacitating complications such as edema, neuralgia, and wound infection. Similarly, injury or damage to the main artery and to its collateral vessels, both in the region of the occlusion as well as above and below this process, must be minimized in order to prevent subsequent thrombosis. The procedure should be done in a manner that will preserve all existing collateral blood vessels in order to prevent further loss of circulation. Thus, while the procedure should be directed toward restoration of a strong pulsatile

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FIG. 1.

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FIG. 2.

FIG. 1. a, Preoperative arteriogram of left superficial femoral artery showing short segmental occlusion with one large and several small collateral branches. b, Postoperative arteriogram of same case showing patent graft but fewer visible collateral branches.

FIG. 2. a, Preoperative arteriogram of right superficial femoral artery showing occlusion with multiple collateral branches. b, Postoperative arteriogram of same case showing patent graft and the same collateral branches as observed preoperatively.

blood flow into the peripheral arterial bed, its performance should be associated with minimal jeopardy to the existing circulatory and functional capacity of the extremity.

The procedure of endarterectomy, except in the very short occlusive lesions, has not completely met these criteria in our experience. Postoperative thrombosis has occurred too often and at least 2 legs were made worse by the operation. Amputation was required in both cases several days later, and dissection of the limbs revealed thrombosis not only in the endarterectomized area, but also extending distally and obliterating essential collaterals. The reported experience of Bazy, Fontain and associates, and Julian and associates has been quite similar.

Complete excision with homograft replacement of an occluded segment has the disadvantages of an extensive operation, particularly in those cases with relatively long lesions. There is greater opportunity for injury to the saphenous nerve, lymphatics, and the adjacent veins. Desirable venous and arterial collateral vessels are sacrificed, thus necessitating considerable reliance on success of the operation for preservation of the extremity (Fig. 1). The extent and difficulty of such an operation, with its possible undesirable sequelae, are distinct disadvantages in those patients who are likely to have heart disease, diabetes, or cerebral arteriosclerosis.

The generally employed type of by-pass operation consists of inserting a graft by end-to-end anastomosis to the host artery above and below the diseased segment after ligating its two ends. Since this segment is often not completely occluded except for a short distance, and may still communicate with collateral vessels, blood flow through them is reduced or abolished by such interruption. Should thrombosis occur in the graft from technical errors or other complication, such as wound infection, the resulting circulation would be less than that existing preoperatively.

The type of procedure that has been found most effective in avoiding these disadvantages and in meeting the requirements described for successful results has been the bypassing operation originally described by Kunlin and his associates. It is based upon

FIG. 3.

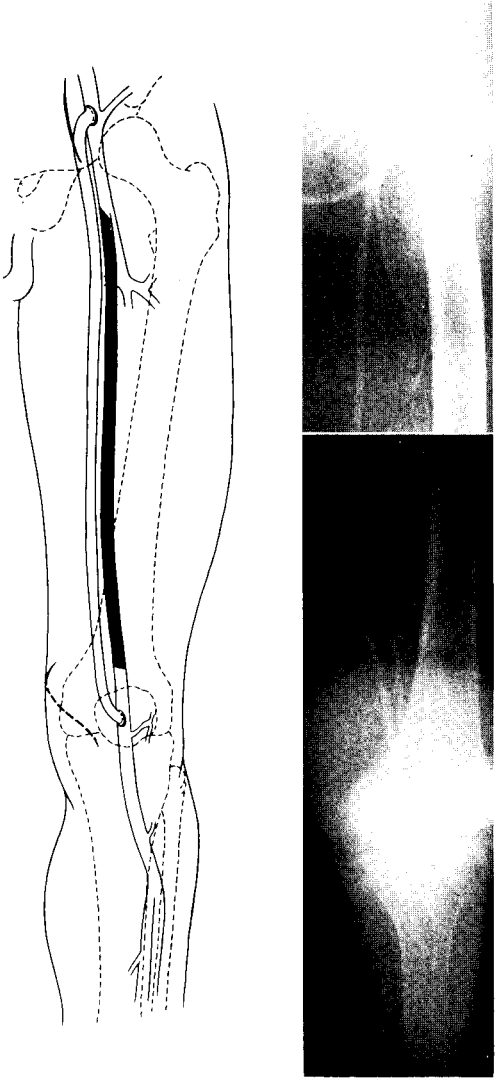

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FIG. 4.

FIG. 3. Postoperative arteriogram of right superficial femoral artery showing patent graft by-passing occlusion and not disturbing the fine arbor of collateral branches at either end of the occluded segment.

FIG. 4. a, Preoperative arteriogram of left superficial femoral artery, showing complete occlusion of the proximal half of this vessel with partial occlusion in distal half but with good lumen in popliteal artery. b, Diagram showing the segment of the superficial femoral artery to be by-passed in solid black. The arterial homograft is anastomosed to the common femoral artery above and to the popliteal artery below. c, Postoperative arteriogram showing patency of the graft and the segment of the host artery which was patent preoperatively still unchanged.

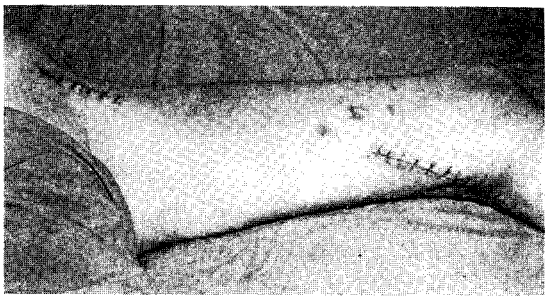

FIG. 5.

FIG. 5. The location of the two incisions used in by-passing a long occluded segment of the femoral artery such as that shown in Figure 4.

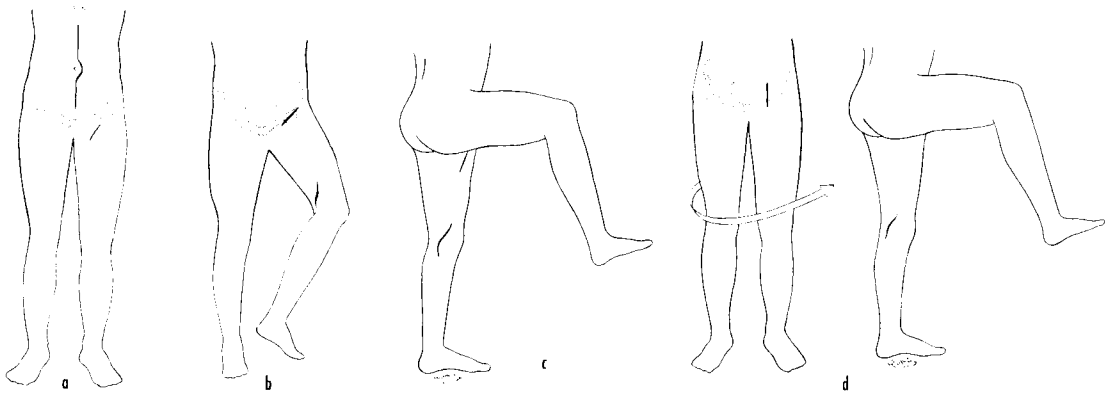

FIG. 6. Diagrams illustrating position of the patient on operating table. a, Supine position for operations to by-pass occlusions involving iliac or upper femoral arteries with midline abdominal incision to expose former artery and oblique incision in upper thigh to expose latter artery. b, Supine position with leg slightly flexed and externally rotated showing upper and lower incisions for operations to by-pass occlusions involving midportion of superficial femoral artery. c, Lateral position with uninvolved leg sharply flexed showing upper and lower incision for occlusions involving lower third of femoral artery. d, Combined supine and lateral position showing high incision to expose upper femoral artery and low incision in order to expose the popliteal artery for long occlusions which involve most of the superficial femoral artery.

the natural response of the arterial tree to an occlusion, which is the enlargement of collateral vessels around the blocked area. In essence the operation simply adds a collateral vessel about the size of the normal artery to those already present without disturbing these vital branches (Figs. 2 and 3). This is accomplished by anastomosing a graft end-to-side to the host artery above and below the diseased segment through two small separate incisions which are connected by a tunnel made with a vein stripper (Figs. 4 and 5). In our experience this method has satisfied best the criteria outlined previously, and it would seem worth while to present in detail the technique of this operation as we have used it, along with a brief analysis of our results with its application in 40 extremities, using lyophilized arterial homografts.

TECHNIQUE

The position of the patient on the operating table determines the ease of exposure, since the two incisions are often widely separated and in different planes of the body. The patient is placed in the supine position for operations to by-pass occluded segments in the iliac or upper femoral arteries (Fig. 6a). For occlusions in the midsuperficial femoral region, the same position is used, but, in addition, the involved leg is slightly flexed and externally rotated to bring the lower incision into the proper plane (Fig. 6b). When the disease is in the lower third of the superficial femoral artery, the patient lies on his side with the involved leg nearest the table and slightly flexed, while the upper or uninvolved leg is sharply flexed, thus exposing both areas to be incised (Fig. 6c). In by-passing long segments when one incision is made high in the groin or abdomen and the other behind the knee, a combination of positions may be necessary (Fig. 6d). This can be accomplished with ease by proper preparation of the skin and adequate draping.

The incisions are from 4 to 10 centimeters in length and are placed to expose the most normal area both above and below the obstruction and at a safe distance from the arbor of collaterals (Fig. 7a). The availability of the arteriogram in the operating room is essential for determining the proper placement of the incisions.

Either incision is made first, and following exposure of the artery above and below, clamps are applied on either side of the area

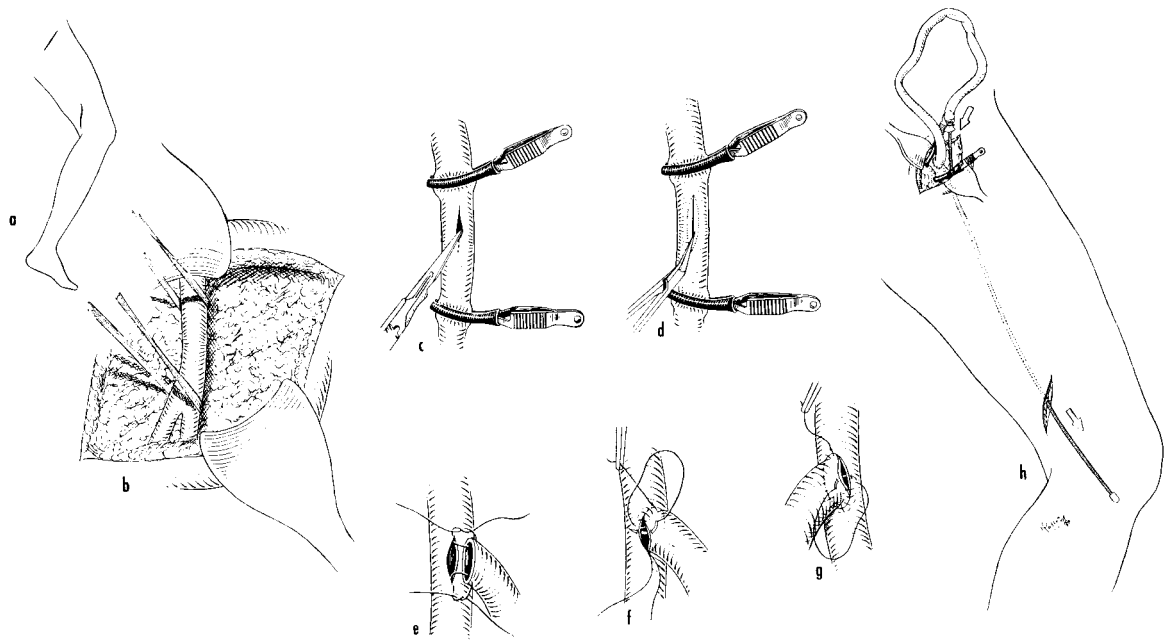

FIG. 7. Technique of performing by-pass procedure for occlusion of superficial femoral artery. a, With patient in supine position and leg slightly flexed and externally rotated upper and lower incisions are made to expose artery well above and below obstruction. b, Common femoral artery is encircled with umbilical tapes after being mobilized for a distance of about 5 centimeters, which in this instance is just above origin of profunda femoris. c, Occluding clamps are applied to the artery and a longitudinal incision about the size of the lumen of the graft is made in its wall anteriorly. d, An oval aperture is made by excising with fine scissors a small elliptic piece from the lateral edges of the wound. e, The end-to-side anastomosis between the bevelled end of the arterial homograft and the opening in the host's artery is begun with two separate sutures of No. 5-0 arterial silk which are fixed at each end of the wound. f, One suture is then used to anastomose one side as a continuous through-and-through stitch and anchored to the free end of the other suture. g, The anastomosis of the other side is done with the other suture in a similar manner. h, After this upper anastomosis is completed the other end of the graft is attached to a vein stripper and drawn through a tunnel previously made by blunt dissection into the lower incision. The procedure is then completed by an end-to-side anastomosis of this end of the graft to the artery which is exposed in the lower incision.

of artery to be incised (Fig. 7b). Ordinary bulldog clamps or other types of atraumatic arterial clamps may be used for this purpose. Following longitudinal incision of the artery a small oval aperture is created by excising with fine scissors a small elliptic piece from the lateral edges of this wound (Fig. 7c and d). The final opening is made equal in size to the greatest diameter of the bevelled end of the graft to be inserted, which in most instances is about the same as that of the host artery.

A reconstituted lyophilized arterial homograft, the ends of which have been slightly bevelled, is then sutured end-to-side to the host artery. A simple over-and-over stitch using No. 5-0 arterial silk is employed. The graft is first fixed to the patient's artery at each end of the wound by a suture that is passed from outside in and out again through the graft (Fig. 7e). Each suture is tied and the needle end of one is passed over and over from outside in through the graft, and from inside out through the host artery (Fig. 7f). The anastomosis of this side is completed by tying the suture to the short end of the other suture. Then using the second suture, the other side of the anastomosis is performed in a similar fashion (Fig. 7g). Accurate approximation is most necessary in order to prevent constriction of the patient's artery.

After the first anastomosis is completed, a tunnel connecting the two incisions is started with blunt dissection using an index finger in each wound. When the distance to be covered is long a vein stripper may be used to complete this procedure, but any long clamp will suffice for shorter distances. The free end of the graft is attached to the end of this instrument and is pulled after it to the opposite incision (Fig. 7h). Rotation or twisting of the graft must be prevented during this procedure. The second anastomosis is then performed using the same technique described before. During the second anastomosis, traction must be applied to the graft in order to attain satisfactory tension at the completion of the operation. The clamps are removed after establishing the second anastomosis and suture line bleeding is controlled by applying dry gauze for a few moments. The wounds are closed and ordinary bandages are applied.

RESULTS

Blood flow through the main arterial channel distal to an occlusion was successfully re-established in 37 of the 40 extremities in which this technique was employed. Success was determined by arteriography or by the presence of palpable pulses distal to the block that were absent prior to operation. The 3 failures were in borderline candidates evidenced by small distal patent segments with secondary occlusions below. Particularly significant is the fact that none of these cases was made worse by the operation. The clinical condition of the extremity and the postoperative arteriograms were unchanged.

The indication for operation in the 37 successful cases was intermittent claudication in 29, gangrene of limited degree in 7, and in 1, extensive gangrene. Among the patients with gangrene, painful ischemic ulcers were present in 2, severe rest pain in 6, and in 1, a digit had been destroyed by associated infection. All the patients with claudication and rest pain were relieved immediately after operation and have remained well. The ulcers in the 2 patients with this complication immediately became painless and healed rapidly. In the patient with the infected toe, amputation of this digit was followed by rapid healing of the stump. A low leg amputation leaving a long stump was successfully performed in the patient with the gangrenous foot, who also had significant lowering of cutaneous temperature at the midthigh level and color changes at the midtibial level. According to previous experience such manifestations would have necessitated a midthigh amputation. In this patient, however, there was sufficient improvement in circulation following insertion of the graft to permit amputation below the knee with a long length stump. The extra length of this stump has been of distinct advantage to this elderly patient, who had had a midthigh amputation on the other side previously.

All the grafts in this series have remained patent since discharge of the patients from the hospital and for periods up to 18 months. No patient has had a recurrence of his difficulties. There were no deaths and only a few complications. A superficial wound infection occurred in 1 patient and thrombophlebitis complicated by a small pulmonary infarct developed in another, but both patients recovered completely without residual disturbances.

SUMMARY

1. The occlusive process in chronic arteriosclerotic arterial insufficiency of the lower extremities is often segmental in nature with a patent vessel above and below it. Owing to this fortunate pathologic feature of the disease it is frequently possible to restore normal circulation in the peripheral arterial bed. This may be accomplished by several methods including thromboendarterectomy, excision of the occluded segment with replacement by a graft, and by-pass of the diseased area with a graft.

2. Our experience with these methods has led us to the conviction that the by-pass procedure, owing to its simplicity in concept

and application, is the most effective in achieving the desired objectives and is associated with the fewest disadvantages. It consists essentially in the addition of a large collateral vessel around the blocked area to those already present, but without disturbing them. Conceptually, therefore, it is based upon the natural response of the arterial tree to an occlusive process, namely, the enlargement of collateral vessels around the obstruction. The procedure is accomplished by the anastomosis of an arterial homograft end-to-side to the patient's artery above and below the occluded segment through two small separate incisions which are connected by a tunnel in the subcutaneous tissues.

3. The most important advantage of this procedure lies in the fact that it not only permits restoration of a normal pulsatile blood flow into the peripheral arterial bed, but also is associated with minimal jeopardy to the existing circulatory and functional capacity of the extremity. The minimal dissection required in its performance reduces the risk of injury and thrombosis to the main artery and to its collateral vessels in the region of occlusion as well as above and below this process. Because adjacent structures such as veins, lymphatics, and nerves are not disturbed, troublesome and even incapacitating complications such as edema, neuralgia, and wound infections are largely prevented.

4. These advantages are well demonstrated by the highly gratifying results obtained in our experience with the application of this procedure in 40 extremities. Restoration of a pulsatile blood flow in the peripheral arterial bed was obtained in all but 3 of the cases. These 3 failures were borderline candidates to begin with, but particularly significant is the fact that none of them was made worse by the operation.

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